Frozen Minced Fish

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
REGIONAL CENTRE
MANGALORE

R.C. Baker
J.M. Regenstein
M. Raccach
J.M. Darfler

Development of Products from Minced Fish: Booklet 3

This is one in a series of booklets on minced fis
products written for people in the food proces
ing industry.

Published by
New York Sea Grant Institute
State University of New York and
Cornell University
411 State Street
Albany, New York 12246

Printed in USA
October 1977
Price $ .75

DEVELOPMENT OF PRODUCTS FROM MINCED FISH:

3. FROZEN MINCED FISH

R. C. Baker, J. M. Regenstein, M. Raccach, and J. M. Darfler

Department of Poultry Science, Rice Hall,

Cornell University, Ithaca, N. Y.

This research was sponsored by the New York Sea Grant Institute under a grant from the Office of Sea Grant, National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce.

ACKNOWLEDGMENTS

We would like to thank the following:

Mrs. Emma Mulnix and Win Chin Hung for the laboratory analyses; Bud Palmer, of Palmer's Fish Market, Rochester, for his enthusiasm and encouragement; and, last but not least, the members of our taste panel.

TABLE OF CONTENTS

INTRODUCTION.....6

PRELIMINARY RESEARCH.....7

Testing Methods.....8

Source and Treatment of Fish.....8

Methods of Evaluation.....8

Taste Paneling.....8
Shear Values.....9
Color Values.....9
Proximate Analyses.....11

Results of Evaluation - Marine Fish.....11

Storage Stability of Nonphosphated Fish.....11

Storage Stability of Phosphated Fish.....12

Thawing Methods.....15

Refrigerated Shelf Life of Thawed Frozen Fish.....16

Results of Evaluation - Fresh Water Species: Mullet.....19

Storage Stability.....19

Thawing Methods.....23

Refrigerated Shelf Life of Thawed Frozen Mullet.....23

Proximate Analyses.....26

Microbiological Studies of Minced Fish.....26

Testing Methods.....26

Results.....28

Effect of Processing.....28
Effect of Freezing.....29
Effect of Thawing.....30
Effect of Refrigerated Storage.....30

Interchangeability of Fish Species.....32

DEVELOPMENT OF THE PACKAGE.....38

TABLE OF CONTENTS (continued)

LARGE SCALE EVALUATIONS.....39

CONCLUSIONS.....39

REFERENCES.....41

TABLES AND FIGURES

TABLE 1 Effect of Two Months' Storage at -23°C (-10°F) on Taste Panel Scores for Several Species of Marine Fish (Unphosphated).....12

TABLE 2 Effect of Storage at -23°C (-10°F) on the Color of Phosphated Whiting, Cod, and Pollock.....13

TABLE 3 Effect of Storage at -23°C (-10°F) on the Aroma, Flavor, Tenderness, and Shear Values of Phosphated Whiting, Cod, and Pollock.....15

TABLE 4 Effect of Thawing Method on Phosphate Treated Minced Marine Fish.....17

TABLE 5 Effect of Refrigerated 4°C (40°F) Storage on Thawed Frozen Phosphate Treated Minced Fish.....18

TABLE 6 Effect of Length of Storage at -23°C (-10°F) And Phosphate Treatment on the Color of Thawed Frozen Mullet.....20

TABLE 7 Effect of Length of Storage at -23°C (-10°F) and Phosphate Treatment on Aroma and Flavor of Thawed Frozen Mullet.....21

TABLE 8 Effect of Length of Storage at -23°C (-10°F) and Phosphate Treatment on Tenderness of Thawed Frozen Mullet.....22

TABLE 9 Effect of Thawing Method on Phosphate Treated Minced Mullet.....24

TABLE 10 Effect of Refrigerated 4°C (40°F) Storage on Thawed Frozen Phosphate Treated Minced Mullet.....25

TABLE 11 Proximate Analysis of Several Species of Minced Fish.....26

TABLE 12 Microbiological Variations During the Further Processing of Cod Frames.....28

TABLE 13 Microbiological Variations During the Further Processing of Headed and Gutted Marine Fish.....29

TABLE 14 The Effect of Freezing and Frozen Storage at -23°C (-10°F) on the Microbiology of Minced Fish Using Several Marine Species.....29

TABLE 15 The Effect of Length of Time of Frozen Storage at -23°C (-10°F) on the Microbiology of Minced Mullet...30

TABLES AND FIGURES (continued)

TABLE 16 The Effect of Thawing Rate on the Microbiology of Minced Fish Using Several Marine Species.....31

TABLE 17 The Microbial Quality of Minced Fish of Several Marine Species Stored at 3°C (37°F).....31

TABLE 18 Microbial Growth in Minced Mullet Stored at 2°C and 12°C.....32

TABLE 19 Formula for Creamy Fish Balls.....34

TABLE 20 Formula for Sweet and Sour Fish Balls.....35

TABLE 21 Formula for Fish Balls in Tomato Sauce.....36

TABLE 22 Effect of Species of Fish on Acceptability of Products Made From Them.....37

FIGURE 1 Representative Score Sheet for Sensory Evaluation of Minced Fish.....10

DEVELOPMENT OF PRODUCTS FROM MINCED FISH:

3. FROZEN MINCED FISH

R. C. Baker, J. M. Regenstein, M. Raccach, and J. M. Darfler

Department of Poultry Science, Rice Hall,

Cornell University, Ithaca, N. Y.

ABSTRACT

In order to evaluate the feasibility of marketing a frozen one-pound box of minced fish at the retail level, a comparison of several potential species of underutilized fish and fish frames was made. Factors investigated included frozen and refrigerated shelf life, effect of thawing method, proximate analyses, and microbiological studies. These species were also tested in several recipes. As a result, minced mullet was selected for market testing. A package was designed, which included instructions for use and a number of recipes.

DEVELOPMENT OF PRODUCTS FROM MINCED FISH:

3. FROZEN MINCED FISH

INTRODUCTION

As part of a long term project concerned with the utilization of minced fish for human consumption, it was decided to investigate the possibility of selling a one-pound package of frozen minced fish directly to the consumer. Previous work had centered on developing several commercial products from this material (Baker et al., 1976a and b). Fish in comparison to other meats has several important nutritional factors in its favor: principally, it is low in fat (and that fat is relatively unsaturated), low in cholesterol, and high in good quality protein. In the minced form it could be used as a low fat hamburger substitute and as a new form of fish. Furthermore, many dishes such as gefilte fish, seafood newburg, French quenelles, and several Oriental stir-fry dishes use ground fish or fish in small pieces.

The concept of direct retail sale had already been evaluated on a relatively small scale in Duluth, Minnesota, by Dale Baker, Director of the Advisory Service, Minnesota Sea Grant, and we decided to try a market test on a larger scale in New York. Dr. Dana Goodrich of our Agricultural Economics Department, planned a market test in Rochester and Ithaca, New York. At the time of this writing, the market test is finished and was successful (Goodrich and Whitaker, 1977).

Deboning Machines

There are two general types of deboning machines on the market in the United States; namely, the auger type and the belt type. When we started working with underutilized species of fish, we purchased an auger type machine which had an excellent reputation for deboning chicken. When deboning fish, however, we have found two distinct disadvantages. The particle size of the deboned fish is small (almost a paste) because the cylinder openings are small (3 mm and less) and the pressure is high, and the product from most species of fish is off colored because of the bits of skin and pigment which are extruded with the flesh. With species of fish that are devoid of the dark pigment or with skinned fish, this discoloration is not a problem. With the belt type deboner the particle size of the minced fish is considerably larger because the cylinder openings are larger (5 to 7 mm) and the end product has little skin and dark pigment because of the lower pressure used. Because of these problems plus the problem of getting fresh fish into Ithaca, we decided to purchase frozen minced fish (from a belt machine) for the market test instead of deboning it ourselves.

PRELIMINARY RESEARCH

Before market testing a new product, research needs to be done on such factors as the effect of different species of fish and properties such as keeping quality, organoleptic properties, and microbiology quality. This section deals with the results of this preliminary research.

Testing Methods

SOURCE AND TREATMENT OF FISH

Marine species of fish (cod [*Gadus morhua*], whiting [*Menticirrhus saxatilis*], yellowtail flounder [*Limanda ferruginea*], and pollock [*Pollachius virens*]) were obtained from a fish wholesaler in Boston. They were iced and transported by refrigerated truck to Ithaca, where they were headed, gutted when necessary, washed (removing all kidney tissues insofar as possible), and deboned in our laboratory using an auger type deboning machine. About 400 gram aliquots were packaged in polyethylene bags for frozen storage at -23°C (-10°F). When "phosphating" was done before freezing, dissolved FREEZ-GARD FP-88 (Stauffer Chemical Co., Pittsburgh, Pa.) at the one percent level was thoroughly stirred in. This material is composed of sodium hexametaphosphate, salt and sodium erythorbate.

White sucker [*Catostomus commersoni*], also known as mullet in parts of the United States and Canada, was obtained from a commercial fish processor in Wisconsin. We obtained the minced fish already labeled mullet, and felt it sounded better than white sucker to the consumer. On arrival at the commercial plant it was deboned using a belt type deboner, packaged in approximately 20 pound blocks, frozen, and shipped to Ithaca by a refrigerated truck.

METHODS OF EVALUATION

Taste Paneling. Samples were evaluated by a seven to eight member taste panel, experienced in the evaluation of fish products.

Members were both male and female, and included housewives, faculty members, and technicians. Judging was done in a well-lit room at individual booths. Water and soda crackers were always available for use between samples.

Score sheets were planned to evaluate the parameters of interest, depending on the product and/or treatment being evaluated. In general, a scale from 9 to 1 was used, 9 representing optimum for all factors except tenderness, in which case 9 = firm, 5 = optimum and 1 = soft. A representative score sheet is shown in Figure 1.

In order to avoid positional bias, sample order was randomized on each of the score sheets.

Sample preparation: For evaluation of shelf life, thawing methods and comparison of species, thawed fish samples were wrapped in squares of aluminum foil, 25 grams per package, coded, then baked for 15 minutes at 190°C (375°F). They were served to the panel as soon as they were removed from the oven, and were opened by each panelist while still hot.

Shear Values. An Allo-Kramer shear press was used for determinations, using the standard shear cell. Samples were cooked by the same method and at the same time as those used for taste paneling, refrigerated in the unopened foil packages, and sheared the following day. A 20 gram sample was sheared, using 10 percent of a 2500 pound proving ring, or 250 pound maximum force. Maximum force required to shear each sample was recorded, and is reported in pounds of force per gram.

Color Values. For determination of color values, a Hunter Color Difference Meter Model No. D25-2 was used. A yellow plate,

FIGURE 1 REPRESENTATIVE SCORE SHEET FOR SENSORY EVALUATION OF MINCED FISH

Name: _____

Date: _____

Product: MINCED FISH

Sample Codes

Color

9 8 7 6 5 4 3 2 1

Desirable (Normal) — Undesirable (Off Color)

Aroma

9 8 7 6 5 4 3 2 1

Appetizing — Off Odor

Flavor

9 8 7 6 5 4 3 2 1

Appetizing — Off Flavor

Tenderness

9 8 7 6 5 4 3 2 1

Firm — Soft

Note: Please describe any off odors or off flavors.

L = 78.2, a = 2.3, b = 22.5 was used as a standard. L values indicate lightness of sample, the higher numbers being lighter, a values indicate redness (+) or greenness (-), while b values indicate yellowness (+) or blueness (-).

Foil-wrapped samples cooked as for taste paneling were refrigerated overnight, unwrapped, and immediately read on the Color Difference Meter. Two readings per sample were taken, the second at right angles to the first (rotated 90°), and the values averaged. Values are reported as L, a, and b values.

Proximate Analyses. Proximate analyses of the minced fish was done by standard AOAC methods (AOAC, 1965). In brief, these methods are as follows:

Moisture - oven drying at 105°C (221°F) for about 18 hours.

Fat - chloroform-methanol extraction for 16 hours on the Goldfisch apparatus.

Protein - Kjeldahl method with colorimetric titration and assuming 16 percent nitrogen for fish protein.

Ash - muffle furnace at 550°C (1022°F) for 24 hours.

Results of Evaluation - Marine Fish

STORAGE STABILITY OF NONPHOSPHATED FISH

Foil packages of cod, whiting, and pollock were baked and presented to the taste panel the day of deboning and after two months of storage at -23°C (-10°F). The thawed frozen fish showed considerable free moisture when the outside surface was disturbed. This was stirred into the fish before weighing onto the foil. Results can be seen in Table 1.

TABLE 1 EFFECT OF TWO MONTHS' STORAGE AT -23°C (-10°F) ON TASTE PANEL SCORES FOR SEVERAL SPECIES OF MARINE FISH (UNPHOSPHATED)

	Species					
	Whiting		Cod		Pollock	
Parameter	1 day*	2 mo	1 day	2 mo	1 day	2 mo
Color	5.3	5.3	6.4	6.2	5.3	5.8
Aroma	5.4	5.0	6.1	4.7	5.9	5.2
Flavor	6.1	4.8	5.0	4.3	6.4	4.5
Tenderness	4.9	7.3	4.4	6.0	6.6	7.8

*One day samples were not frozen.

A nine-point scale was used, the higher numbers denoting the more desirable attributes, except for tenderness, where 9 = firm, 5 = optimum, and 1 = soft.

A seven member taste panel evaluated the samples twice.

Color scores appeared to have changed little after two months but the aroma and flavor had deteriorated in all samples. The taste panelists described the flavor as fishy and stale, especially in the case of cod and whiting. Tenderness scores rose, indicating a less tender product. This difference was greatest for cod, least for pollock, which was firmer when fresh than the other two fish.

STORAGE STABILITY OF PHOSPHATED FISH

To investigate the effect of phosphating on these species, three species of fish (cod, whiting and pollock) were mixed with phosphate following deboning, then taste paneled. Samples were packaged in polyethylene freezer bags, frozen and stored at -23°C

(-10°F), and re-evaluated at 40 and 90 days. Effect of storage time on color can be seen in Table 2.

TABLE 2 EFFECT OF STORAGE AT -23°C (-10°F) ON THE COLOR OF PHOSPHATED WHITING, COD, AND POLLOCK

	Species								
	Whiting			Cod			Pollock		
Parameter	1 day*	40 days	90 days	1 day	40 days	90 days	1 day	40 days	90 days
Taste panel scores									
Color	7.6	5.6	3.3	7.6	5.3	4.3	5.0	5.3	5.4
Hunter values									
L	57.5	51.4	41.2	54.2	40.6	39.1	52.1	52.4	50.5
a	0.8	3.2	8.6	2.2	6.6	8.2	0.7	-0.4	5.7
b	9.9	4.6	4.0	6.1	1.7	1.8	7.6	6.7	5.6

*One day samples were not frozen.

A nine-point scale was used for color, where 9 = most desirable. An eight member taste panel evaluated these samples.

Taste panel color scores for whiting and cod showed a drastic change for the worse. Pollock, however, showed little if any change due to storage time. Hunter values showed a definite darkening (decreasing L values) in the cod and whiting samples, with little or no change in the pollock. Whiting appeared to become slightly redder (increasing +a values) and less yellow (decreasing +b values) with storage time, while cod showed only a decrease in yellowness.

Table 3 shows the effect of storage on aroma and flavor scores. Whiting showed a decrease in both aroma and flavor, cod showed

little change in aroma but a slight decrease in flavor, while pollock changed little if any in these areas. Comments from the taste panel after 90 days of storage included "fishy, bitter, sour, musty, stale, and off" for whiting and "objectionable flavor, stale, sour, and off" for cod. It should be noted that none of these comments included "rancid". Pollock comments included "good" and "not bad".

Toughness as evidenced by both taste panel scores and shear values increased drastically with storage in the case of cod and whiting, and to a lesser extent in the case of pollock (Table 3).

It can be concluded that the storage stability of minced pollock, when deboned by an auger type machine, is considerably better than that of cod and whiting. Addition of phosphates, however, has little or no effect on the changes that occur during frozen storage in the areas of tenderness, flavor, or aroma. Thaw drip is unaffected by the addition of phosphates when thawed to 4°C (40°F); it appears to be held within the spongy texture of the fish after thawing but can be squeezed out with slight pressure, but as the temperature rises, the drip increases in untreated fish considerably more than in phosphated fish. In addition, phosphated minced marine fish handles better when making many products than unphosphated fish.

Texture changes occurring during frozen storage for fish of the gadoid species (cod, pollock) have been studied by many researchers (Love and Elerian, 1965; Cowrie and Little, 1966; Connell and Howgate, 1968; Anderson and Ravesi, 1969; ibid, 1970; Bykova, 1972). The principal reason for toughening appears to be directly related

TABLE 3 EFFECT OF STORAGE AT -23°C (-10°F) ON THE AROMA, FLAVOR, TENDERNESS, AND SHEAR VALUES OF PHOSPHATED WHITING, COD, AND POLLOCK

	Species								
	Whiting			Cod			Pollock		
Parameter	1 day*	40 days	90 days	1 day	40 days	90 days	1 day	40 days	90 days
Taste panel scores									
Aroma	6.6	5.3	4.9	5.4	4.8	5.1	5.2	5.9	6.1
Flavor	7.0	5.8	3.5	5.4	5.0	4.1	5.0	5.5	5.5
Tenderness	3.8	6.2	8.4	3.4	7.0	8.0	5.0	6.5	8.0
Shear values (lb/g)	0.7	3.2	6.3	0.7	4.7	6.2	1.6	3.3	4.0

*One day samples were not frozen.

A nine-point scale was used for aroma and flavor scores, the higher numbers denoting the more desirable attributes, for tenderness, 9 = firm, 5 = optimum, and 1 = soft.

to the presence of a dark muscle tissue enzyme which is capable of producing formaldehyde and dimethylamine from the trimethylamine oxide of the muscle (Dingle and Hines, 1975). Among other factors, the formaldehyde has a toughening effect on the fish flesh by polymerization or cross linkages between protein molecules (Castell et al., 1973).

THAWING METHODS

Samples of fish, in approximately one-pound packages, were thawed in their original wrappings (polyethylene bags) by the following methods: (1) in a refrigerator at 4°C (40°F), (2) at

room temperature, 23°C (72°F), (3) in cold water, 10°C (50°F), and (4) in warm water, originally 38°C (100°F). Approximate times required to thaw the packages to about 4°C (40°F) in the center were as follows: method 1 - 24 hours; 2 - 5 hours; 3 - 3 hours; and 4 - 1 hour. All fish was prepared in individual foil packages as described earlier. The fish had been frozen a maximum of five weeks before thawing.

Results of these tests can be found in Table 4. In general, little if any consistent organoleptic or color differences can be found among the thawing methods. However, total bacterial counts (Table 16, page 31) for 10°C and 38°C (50°F and 100°F) (water thawing methods) were slightly lower in most cases.

We wish to point out that in this study the fish was foil packaged and cooked as soon as completely thawed. In cases when the fish may be thawed at the warmer temperatures (23°C and 38°C) and through oversight not used or refrigerated as soon as thawed, no doubt changes would take place, particularly in odor, flavor, and total bacterial counts. Because of this we do not recommend using these thawing methods without caution.

REFRIGERATED SHELF LIFE OF THAWED FROZEN FISH

Samples of fish, phosphate treated, were taken out of frozen storage and moved to a home-type refrigerator set at 4°C (40°F) and held for three, seven, and 10 days. On the day of testing another package of fish was thawed in the original package in an outer plastic bag (in case the outer package leaked) in cold water at 10°C (50°F) as a 0-day sample. Whiting, cod, and pollock were evaluated in this manner. Results can be seen in Table 5.

TABLE 4 EFFECT OF THAWING METHOD ON PHOSPHATE TREATED MINCED MARINE FISH

Parameter	Thawing method			
	Air 4°C	Air 23°C	Water 10°C	Water 38°C
		Whiting		
Taste panel scores				
Color	5.3	5.7	5.5	5.3
Aroma	5.2	6.1	5.7	5.4
Flavor	5.8	6.1	6.2	5.4
Tenderness	5.7	5.6	5.7	5.3
Shear Values (lb/g)	3.1	3.1	3.3	2.4
Hunter values				
L	56.8	56.0	55.8	56.9
a	-0.7	-0.6	-0.7	-0.9
b	10.3	9.7	9.4	9.2
		Cod		
Taste panel scores				
Color	5.5	5.5	5.5	5.4
Aroma	5.5	5.4	5.6	5.3
Flavor	5.3	5.5	5.6	5.2
Tenderness	5.7	5.8	5.5	5.6
Shear values (lb/g)	3.3	3.0	2.5	2.6
Hunter values				
L	52.3	54.3	52.3	53.1
a	-1.8	-1.9	-2.0	-1.9
b	6.4	7.0	6.1	6.4
		Pollock		
Taste panel scores				
Color	4.4	4.7	5.3	5.0
Aroma	4.6	4.7	5.9	5.1
Flavor	4.6	5.3	5.5	4.9
Tenderness	7.0	6.3	6.5	6.5
Shear values (lb/g)	4.0	3.5	3.3	3.4
Hunter values				
L	52.4	53.5	52.4	52.9
a	-0.3	-0.1	-0.4	-0.6
b	6.8	6.9	6.7	6.8

A nine-point scale was used for color, aroma and flavor scores with 9 = optimum; for tenderness 9 = firm, 5 = optimum, 1 = soft.

An eight member taste panel evaluated the samples.

TABLE 5 EFFECT OF REFRIGERATED 4°C (40°F) STORAGE ON THAWED FROZEN PHOSPHATE TREATED MINCED FISH

Parameters	Days of storage 0	3	7	10
			Whiting	
Taste panel scores				
Color	5.9	6.0	4.7	4.1
Aroma	5.9	5.3	4.3	3.8
Flavor	7.0	5.2	4.1	4.0
Tenderness	5.3	5.7	6.8	7.9
Shear values (lb/g)	2.7	3.2	3.7	5.6
Hunter values				
L	61.9	56.2	57.2	52.7
a	-0.5	-0.3	-0.4	-1.3
b	7.2	9.5	9.2	10.5
			Cod	
Taste panel scores				
Color	6.2	6.4	6.1	4.3
Aroma	5.9	6.0	5.3	5.0
Flavor	6.2	6.5	5.3	4.0
Tenderness	5.8	6.2	6.1	7.7
Shear values (lb/g)	2.8	2.9	3.4	5.6
Hunter values				
L	58.7	57.3	57.4	52.1
a	-1.7	-1.7	-1.4	-1.2
b	7.7	8.0	8.4	5.2
			Pollock	
Taste panel scores				
Color	4.3	3.4	3.7	3.0
Aroma	5.0	5.0	4.4	3.9
Flavor	5.0	4.3	3.7	3.1
Tenderness	6.4	8.4	8.1	8.7
Shear values (lb/g)	5.8	5.8	6.8	7.1
Hunter values				
L	51.9	47.7	47.9	43.9
a	-1.4	-0.4	-1.1	-0.6
b	10.3	10.7	10.5	9.4

A nine-point scale was used for taste panel scores, the higher numbers denoting the more desirable attributes, except for tenderness, where 9 = firm, 5 = optimum, and 1 = soft.

An eight member taste panel evaluated the samples twice.

On the basis of these results we would recommend using refrigerated thawed frozen fish of any of the species tested as soon as possible and within three days at the most. At seven days of storage considerable changes had occurred for almost all the parameters evaluated for all the marine species.

Results of Evaluation - Fresh Water Species: Mullet

STORAGE STABILITY

Samples of different batches of phosphated mullet which had been stored one month, two months, four months, and eight months, and unphosphated fish stored two months and four months were compared. Table 6 shows the effect of storage and phosphate on taste panel color scores and Hunter color values. There appears to be a difference between months (samples) as well as between treatments, which may be due to the fish having been harvested at slightly different times of the year, but in general the phosphated samples were darker, redder and less yellow.

Phosphating had a beneficial effect on panel scores for aroma and flavor (Table 7), there being essentially no change in scores for fish stored for one month and four months, while the unphosphated samples showed a decrease in aroma scores with time and an even greater decrease in flavor scores. Phosphated fish after eight months of storage had better aroma and flavor than unphosphated fish stored only two or four months.

Toughness (Table 8) increased (higher tenderness scores, higher shear values) with storage time in the unphosphated samples and showed little change in the treated samples. Thaw drip was also

TABLE 6 EFFECT OF LENGTH OF STORAGE AT -23°C (-10°F) AND PHOSPHATE TREATMENT ON THE COLOR OF THAWED FROZEN MULLET

Storage time (mo)	Treatment	Color scores	Hunter values		
			L	a	b
1	Phosphate	6.9	52.7	2.7	4.1
2	Phosphate	6.4	47.9	5.8	2.9
2	No phosphate	5.0	57.0	0.8	9.2
4	Phosphate	3.7	47.3	5.8	3.1
4	No phosphate	3.8	51.9	3.7	9.6
8	Phosphate	4.4	45.3	6.5	2.3

Higher color scores denote more acceptable color on a scale from 9 to 1.

An eight member taste panel evaluated the samples; all storage times and treatments were sampled on the same days.

TABLE 7 EFFECT OF LENGTH OF STORAGE AT -23°C (-10°F) AND PHOSPHATE TREATMENT ON AROMA AND FLAVOR OF THAWED FROZEN MULLET

Storage time (mo)	Treatment	Taste panel scores	
		Aroma	Flavor
1	Phosphate	5.6	6.1
2	Phosphate	6.6	6.1
2	No phosphate	5.0	4.6
4	Phosphate	6.1	6.4
4	No phosphate	4.4	3.4
8	Phosphate	5.6	5.4

Higher taste panel scores denote better aroma and flavor, on a scale from 9 to 1.

An eight member taste panel evaluated the samples; all storage times and treatments were sampled on the same days.

TABLE 8 EFFECT OF LENGTH OF STORAGE AT -23°C (-10°F) AND PHOSPHATE TREATMENT ON TENDERNESS OF THAWED FROZEN MULLET

Storage time (mo)	Treatment	Tenderness scores	Shear values (lb/g)
1	Phosphate	4.9	2.5
2	Phosphate	4.4	1.8
2	No phosphate	6.0	3.7
4	Phosphate	5.1	2.0
4	No phosphate	7.2	5.9
8	Phosphate	5.7	3.1

A nine-point scale was used for tenderness scores where 9 = firm, 5 = optimum, and 1 = soft.

An eight member taste panel evaluated these samples twice; all storage times and treatments were sampled on the same days.

decreased from about five percent to two percent by phosphating.

Treatment with phosphate appears to have a definite beneficial effect on frozen minced mullet, protecting aroma, flavor, and tenderness. In addition, phosphated minced mullet handles better when making many products than unphosphated mullet.

THAWING METHODS

Samples of frozen minced mullet were thawed by the same methods as the marine fish species. As can be seen by the data in Table 9, the taste panel in general scored samples that were thawed more slowly as having better color, and samples thawed in air as having slightly better flavor, but no other trends are apparent. It would appear from these data that the thawing method made very little difference in the final product, but once again it must be remembered that these samples were cooked soon after thawing. If this were not the case, however, and the fish were allowed to remain under the warmer conditions, no doubt objectionable flavors and bacterial build-up would occur.

REFRIGERATED SHELF LIFE OF THAWED FROZEN MULLET

Storage at 4°C (40°F) up to 10 days (Table 10) resulted in a change in color scores, which, as indicated by the Hunter color values, included darkening, increased yellowness, and decreased redness. Aroma scores changed little, but flavor scores were much lower, even at three days of storage. Although the taste panel did not pick up a toughening effect, shear values were higher after the first three days of storage. On the basis of the drop in flavor scores, our recommendation would be not to use

TABLE 9 EFFECT OF THAWING METHOD ON PHOSPHATE TREATED MINCED MULLET

Parameter	Thawing method			
	Air 4°C	Air 23°C	Water 10°C	Water 38°C
Taste panel scores				
Color	6.5	5.8	6.4	6.1
Aroma	5.6	5.8	5.8	5.4
Flavor	5.8	5.7	5.3	5.6
Tenderness	5.7	6.0	6.0	5.9
Shear values (lb/g)	1.9	1.6	1.5	1.9
Hunter values				
L	53.8	53.7	53.5	54.7
a	-0.3	2.2	1.0	0.7
b	9.9	9.0	8.4	10.4

A nine-point scale was used for taste panel scores, the higher numbers denoting the more desirable attributes, except for tenderness, where 9 = firm, 5 = optimum, and 1 = soft.

A seven member taste panel evaluated the samples four times.

TABLE 10 EFFECT OF REFRIGERATED 4°C (40°F) STORAGE ON THAWED FROZEN PHOSPHATE TREATED MINCED MULLET

Parameter	Days of storage 0	3	7	10
Taste panel scores				
Color	7.4	7.2	6.9	6.5
Aroma	6.1	6.0	6.0	5.7
Flavor	6.1	5.3	4.8	4.7
Tenderness	5.5	5.7	5.1	5.6
Shear values (lb/g)	1.5	1.5	2.0	2.7
Hunter values				
L	54.7	53.5	52.5	50.5
a	0.7	3.5	4.2	6.1
b	10.4	3.4	3.0	2.7

A nine-point scale was used for the taste panel scores, the higher numbers denoting the more desirable attributes, except tenderness, where 9 = firm, 5 = optimum, and 1 = soft.

A seven member taste panel evaluated the samples twice.

this fish beyond three days or as soon as possible after it is thawed, even when held at 4°C.

Proximate Analyses

Table 11 shows that the species of minced fish which were investigated were very much lower in fat, higher in water, and slightly lower in protein when compared to most red meats. Minced fish is slightly higher in water than comparable fillets because in the deboning operation, liquid is pressed from the bone marrow. It was found that in general, when cooking with low fat fish species, the addition of about an ounce of vegetable oil per pound of fish improved the mouthfeel in most recipes, and the fat content of the resulting combination was still less than 10 percent.

TABLE 11 PROXIMATE ANALYSES OF SEVERAL SPECIES OF MINCED FISH

Species	Water	Fat	Protein	Ash
	(%)	(%)	(%)	(%)
Whiting	82.7	1.0	15.2	0.9
Cod	83.7	0.9	16.0	0.9
Pollock	82.2	1.8	15.1	1.2
Flounder (racks)	82.9	3.5	13.2	0.9
Mullet	81.6	0.8	16.7	1.4

Microbiological Studies of Minced Fish

TESTING METHODS

In order to monitor the potential safety and quality hazards of the frozen minced fish, microbiological evaluations were

conducted. Fish after mincing was stored at -23°C (-10°F). The samples were thawed in air to an internal temperature of 2°C (36°F) under the following conditions: 4.4°C (40°F) (which represents the temperature that is most generally used), 10°C (50°F), 23°C (73°F), and 38°C (100°F). Refrigerated storage studies were conducted at 2°C (36°F), an ideal storage temperature for meats, and at 12°C (54°F) which is an improper storage or "abuse" temperature.

Standard Methods Agar (BBL) in prepoured plates were used as the medium for growing the bacteria. The fish before deboning were sampled by shaking the entire fish in a 0.1 percent Bacto-Peptone solution (Difco). The minced fish (10 grams) was blended in a Waring blender for two minutes with the same diluent. Serial dilutions (1/10, 1/100, 1/1000,etc.) were made as necessary to obtain the 30 to 300 colony forming units (CFU) per plate needed for an accurate count of the bacteria on a plate. Plates were incubated at 25°C (77°F) for 36 to 48 hours for total bacterial counts, at 7°C (45°F) for the total psychrotrophic counts, and at 35°C (95°F) for total mesophilic counts. The psychrotrophs are cold-loving bacteria and have been implicated in the spoilage of fish; the mesophiles are bacteria with optimum growth in the range of 20° to 45°C (68° to 113°F).

Total coliforms (which may be an indication of fecal matter and/or improperly washed hands) and coagulase positive Staphylococcus (a potential food poisoning organism) were also tested according to standard AOAC (1976) methods. Because the number of coliforms found was usually quite small, the results are reported as the most probable number (MPN) (essentially a statistical

approach) rather than actual colony forming units. No coagulase positive Staphylococcus were found in these experiments.

RESULTS

Effect of Processing. Cod frames (gutted) were sampled prior to and after both washing and deboning (Table 12). The results show that washing reduced the total count about 10 fold and the coliform count about three fold. After deboning the frames had a count similar to that before washing, but the coliform numbers were not as greatly increased and were still lower than initially. Headed and gutted fish which were sampled before and after deboning also showed an approximately 10 fold increase in numbers (Table 13). This increase is probably due to better dispersion of the bacteria following deboning.

TABLE 12 MICROBIOLOGICAL VARIATIONS DURING THE FURTHER PROCESSING OF COD FRAMES

Sample	Total count/g	Total coliform/g*
Unwashed frames	2.0×10^6	660
Washed frames	1.5×10^5	230
Mechanically deboned flesh	1.7×10^6	350

*Most probable number

TABLE 13 MICROBIOLOGICAL VARIATIONS DURING THE FURTHER PROCESSING OF HEADED AND GUTTED MARINE FISH

Species	Total count/g	
	Headed-gutted fish	Mechanically deboned product
Cod	4.7×10^4	7.0×10^5
Pollock	5.2×10^4	4.7×10^5
Whiting	7.7×10^4	5.0×10^5

Effect of Freezing. After storage for two weeks, minced marine fish was thawed at 3°C for 18 hours and the total microbial count determined (Table 14). In all cases the final count was lower (by 50 to 80 percent) after thawing than before freezing.

TABLE 14 THE EFFECT OF FREEZING AND FROZEN STORAGE AT -23°C (-10°F) ON THE MICROBIOLOGY OF MINCED FISH USING SEVERAL MARINE SPECIES

Sample	Total count/g		
	Cod	Pollock	Whiting
Unfrozen	7.0×10^5	4.7×10^5	5.0×10^5
Frozen storage (2 weeks)*	1.4×10^5	1.4×10^5	2.5×10^5

*The frozen products were thawed at 3 ± 1°C (37 ± 1°F) for 18 hours.

A more detailed study (Table 15) was made of the minced mullet. This fish was obtained as a minced frozen material. Different lengths of frozen storage were tested and counts were obtained

for mesophiles, psychrotrophs, and coliforms. These results show a decrease over time in the mesophilic population, and little or no change in psychrotrophs or coliforms.

TABLE 15 THE EFFECT OF LENGTH OF TIME OF FROZEN STORAGE AT -23°C (-10°F) ON THE MICROBIOLOGY OF MINCED MULLET

Storage time (mo)	Total count/g		MPN*
	Mesophiles	Psychrotrophs	Coliform
0	1.9×10^6	1.5×10^6	180
1	1.7×10^6	1.1×10^6	180
2	9.5×10^5	1.2×10^6	200
3	5.6×10^5	1.4×10^6	250

*Most probable number.

Thawed at ambient room temperature to 2°C in center.

Effect of Thawing. Thawing rate (Table 16) appeared to have little effect on the total count for the marine species. However, it must be remembered that the thawing was carefully controlled and sampling was done as soon as the flesh reached an internal temperature of 2°C.

Effect of Refrigerated Storage. Storage of the marine species at 3°C increased the total count each day about five to 10 fold and "off-odors" were detected when the counts reached 10^8 to 10^9. This means that the cod and whiting has a three to four day shelf life under these conditions, as can be seen in Table 17, and the pollock about five days.

TABLE 16 THE EFFECT OF THAWING RATE ON THE MICROBIOLOGY OF MINCED FISH USING SEVERAL MARINE SPECIES

Thawing rate °C/hr at (temp.)	Total count/g		
	Cod*	Pollock*	Whiting*
1.2 (4.4°C)	1.6×10^5	2.7×10^5	3.7×10^5
1.6 (10°C)	8.4×10^4	2.9×10^5	2.8×10^5
5.0 (23°C)	1.0×10^5	3.8×10^5	3.3×10^5
12.5 (38°C)	8.3×10^4	1.3×10^5	2.4×10^5

*The total counts of the unfrozen samples were as follows: Cod - 7.0×10^5/g; Pollock - 4.7×10^5/g; and Whiting - 5.0×10^5/g.

TABLE 17 THE MICROBIAL QUALITY OF MINCED FISH OF SEVERAL MARINE SPECIES STORED AT 3°C (37°F)

Storage time (day)	Total count/g		
	Cod	Pollock	Whiting
0*	1.4×10^5	1.4×10^5	2.5×10^5
1	4.7×10^5	6.1×10^5	1.8×10^6
2	2.5×10^6	3.2×10^6	1.7×10^8
3	1.0×10^8	3.5×10^7	2.5×10^8
4	1.4×10^9	1.5×10^8	1.5×10^9
5	8.3×10^9	6.4×10^8	1.1×10^9

*The samples were stored at -23°C (-10°F) for 14 days before examination.

The minced mullet (Table 18) was studied for both psychrotrophs and mesophiles at both ideal and abuse storage conditions. At both temperatures the psychrotrophic initial count was high and increased faster initially than the mesophilic group. Both groups leveled off at about 10^9 or so. At 12°C these numbers were reached at three days while the same counts were not reached for six or seven days at the lower storage temperature. This again clearly illustrates the value of proper refrigerated storage.

TABLE 18 MICROBIAL GROWTH IN MINCED MULLET STORED AT 2° and 12°C

Storage time (day)	Total count/g			
	Psychrotrophs		Mesophiles	
	2°C	12°C	2°C	12°C
0	2.0×10^6	2.0×10^6	1.0×10^6	1.0×10^6
1	-	3.0×10^7	1.5×10^6	5.0×10^6
2	-	4.0×10^8	-	2.5×10^7
3	7.5×10^7	6.5×10^9	2.5×10^6	1.5×10^9
4	-	3.5×10^9	-	9.5×10^8
5	7.0×10^8	-	1.0×10^7	-
6	-	-	7.5×10^8	-
7	5.0×10^9	-	5.5×10^9	-

Interchangeability of Fish Species

At certain times some fish species may be more abundant than others or a certain species may be unobtainable. In order to find

out if species of fish are interchangeable, identical recipes were used, except for the minced fish component. Dishes made included creamy fish balls, sweet and sour fish balls, and fish balls in tomato sauce. Taste panel scores and shear press values were used to evaluate differences. At the time of these experiments, whiting was unobtainable and minced flounder (from racks) was substituted.

Formulas for these products are shown in Tables 19, 20, and 21.

As can be seen in Table 22, in the creamy fish balls, the mullet and the flounder gave a product that was slightly more acceptable, due partly to the fact that they were closer to optimum tenderness (cod and pollock made a product that was judged too soft) and partly because the flavor was better. Shear values confirmed that the mullet and flounder made slightly firmer products.

Overall desirability scores for the sweet and sour fish balls (Table 22) were also higher for products made from mullet and flounder, although in this case the reasons were not as obvious; it appeared to be a combination of factors, including the texture of both preferred species and possibly the juiciness of the mullet and the flavor of the flounder.

In the case of the fish balls in tomato sauce (Table 22), overall desirability scores showed a slight preference for flounder, probably based on its being closest to optimum in tenderness and having very slightly higher scores for juiciness and flavor.

Conclusions to be drawn are: (1) species of fish cannot be indiscriminately used interchangeably in any given formula,

TABLE 19 FORMULA FOR CREAMY FISH BALLS

Ingredient	%
Fish Balls	
Minced fish	65.0
Water	8.0
Textured soy protein (Promate 111, Griffith Labs)	5.0
Fibrous soy protein (SPF200, Ralcon Foods)	5.0
Egg	5.0
Bread crumbs, dry (Nabisco)	4.0
Onions (fresh, chopped)	4.0
Non-fat milk solids	2.0
Salt	1.0
Monosodium glutamate	0.8
Pepper	0.1
Nutmeg	0.1
Vegetable oil for frying	
Gravy	
Milk (whole)	85.0
Vegetable oil	10.0
Cornstarch	3.0
Soy sauce	1.0
Salt	0.8
Onion powder	0.2

Procedure: Mix all fish ball ingredients for about two minutes in a Hobart K5 mixer with paddle attachment at medium speed (#2). Shape into balls, approximately 10 grams in size. Fry in a small amount of oil until slightly brown, removing as they are browned.

When all are done, make gravy with oil remaining in the pan plus enough more to make the required amount. Stir cornstarch with a small amount of milk. Add remaining ingredients to pan; bring to a boil; stir in cornstarch slurry. Cook until thickened. Add fish balls and simmer slowly for 20 minutes. Cover, cool, package, and freeze.

TABLE 20 FORMULA FOR SWEET AND SOUR FISH BALLS

Ingredient	%
Fish Balls	
Minced fish	85.0
Textured soy protein (Promate 111, Griffith Labs)	5.5
Onion (fresh, diced)	4.0
Soy sauce	1.5
Vinegar (5% acidity)	1.5
Sugar	1.0
Seafood Base 85 (The Nestle Co.)	0.8
Parsley (fresh, chopped)	0.5
Salt	0.2
Oil for frying	
Sauce	
Juice, pineapple + water	50.0
Pineapple, chunks	24.0
Green pepper (fresh, diced)	9.0
Vinegar (5% acidity)	9.0
Soy sauce	3.0
Sugar	2.7
Cornstarch	2.0
Salt	0.3

Procedure: Beat all ingredients in a Hobart K5 mixer with a paddle until sticky (about two minutes), shape into small balls approximately 10 grams in size. Fry in oil until lightly browned. Simmer in sauce 20 minutes.

Mix cornstarch in sufficient pineapple juice and water to make a slurry. Heat all remaining ingredients to boiling, add starch mixture, and cook until thickened. Add fish balls, cook 15 minutes, add green pepper and pineapple, and cook 5 minutes longer. Cover, cool, package, and freeze.

TABLE 21 FORMULA FOR FISH BALLS IN TOMATO SAUCE

Ingredient	%
Fish Balls	
Minced fish	86.0
Textured soy protein (Promate 111, Griffith Labs)	6.4
Fibrous soy protein (SPF200, Ralcon Foods)	4.0
Salt	1.4
Onion (fresh, minced)	1.0
Monsodium glutamate	0.6
Parsley (fresh, minced)	0.2
Oregano (dried)	0.12
Garlic (dehydrated)	0.10
Pepper	0.10
Basil (dried)	0.08
Sauce	
Water	84.77
Tomato paste	11.0
Starch	1.0
Salt	1.0
Garlic (dehydrated)	1.0
Sugar	0.7
Onion powder	0.5
Oregano (dried)	0.02
Basil (dried)	0.01

Procedure: Mix all ingredients together until sticky, allow to stand, refrigerated, for 1 to 1½ hours. Shape into small balls, and deep fry for 30 seconds at 190°C (375°F). Mix sauce ingredients and bring to a boil. Fill cans, cover with sauce, and process.

TABLE 22 EFFECT OF SPECIES OF FISH ON ACCEPTABILITY OF PRODUCTS MADE FROM THEM

Parameter	Species			
	Mullet	Cod	Pollack	Flounder
		Creamy Fish Balls		
Taste panel scores				
Texture	5.1	4.3	4.8	5.9
Tenderness	5.3	2.9	3.4	5.4
Juiciness	5.5	4.5	5.0	5.4
Flavor	5.4	4.4	4.6	5.5
Overall desirability	5.1	4.1	4.8	5.6
Shear values (lb/g)	1.7	1.3	1.4	1.7
		Sweet and Sour Fish Balls		
Taste panel scores				
Texture	6.4	5.4	5.6	6.3
Tenderness	6.0	5.4	6.5	5.4
Juiciness	5.8	6.1	4.9	4.9
Flavor	5.1	4.5	4.9	6.0
Overall desirability	6.1	5.3	5.6	6.1
Shear values (lb/g)	4.1	3.7	4.8	3.8
		Fish Balls in Tomato Sauce		
Taste panel scores				
Texture	5.1	5.1	5.1	5.4
Tenderness	4.5	4.0	5.4	4.9
Juiciness	4.9	5.4	4.9	5.6
Flavor	4.1	4.9	4.5	5.0
Overall desirability	4.1	4.5	4.4	5.1
Shear values (lb/g)	1.1	1.2	1.4	1.3

A nine-point scale was used for taste panel scores, where 9 = optimum except for tenderness, where 9 = too tough, 5 = optimum, and 1 = too soft.
An eight member taste panel evaluated the products.

although by reformulation some species may be utilized, and (2) some dishes are more affected by changing species than others.

DEVELOPMENT OF THE PACKAGE

A package was developed consisting of a crystalline wax-coated cardboard box (5-1/4" x 4" x 1-1/2") sized to hold one pound of minced fish overwrapped and heat-sealed with crystalline wax-coated paper. This material is often used as packaging for frozen vegetables. A picture of the package can be seen on the back cover of this publication. The label consisted of two parts. A pressure-sensitive strip covered the entire back and two long sides, designed to remain on the package during storage in the purchaser's freezer, and included instructions on handling before thawing. The remainder of the label was a small recipe booklet with the top package label as its cover, held on by a heat-sealed cellophane oversleeve. The recipe book consisted of an introduction to acquaint the public with this new concept, thawing instructions, and laboratory-tested recipes sufficient to encourage repeat purchases (Goodrich and Whitaker, 1977).

The introduction and thawing instructions were as follows: "You have purchased a package of frozen, deboned (minced) fish meat. Though the texture may seem more like hamburger than fish, it is almost identical in nutritional quality (low in fat, high in protein, and low in calories) to fish purchased in more traditional forms. The tested recipes in this booklet will help demonstrate the product's versatility and give you some ideas for using it.

"Methods of thawing: 8-10 hours in the refrigerator or until the product can be broken apart with a fork but still has some ice crystals remaining. If you must rush the thawing process, put the unopened package in cold water for about 1-1/2 hours, turning it over occasionally."

LARGE SCALE EVALUATIONS

The phosphated mullet, packaged in one-pound packages, was used to make dishes which were served to many large groups. Use of this product was demonstrated at Oceans Festival '76 at the New York Aquarium, to a group of school dieticians, to several groups of chefs including the Culinary Institute of America, and over NBC television in New York and Los Angeles by Jo Geise Brown. It was used in cooking demonstrations in several classes and for other groups, such as open houses, so that many people of all ages were exposed to the concept of "minced fish" and many have also sampled products made from it. Several commercial companies have expressed an interest in using minced fish in their products.

CONCLUSIONS

From the results of this research, it can be seen that phosphated mullet has superior storage stability compared to the marine species studied. When deboned with a belt type deboner, the fish has an appearance somewhat like hamburger, although lighter in color. When thawed, little or no drip is visible in the package, which makes the product attractive to the consumer.

It also is adaptable to use in many recipes which use both hamburger meat and fish in small pieces. On the basis of these facts, as well as the availability of supply, it was decided to evaluate the potential of frozen minced mullet in one-pound packages as a retail item in selected supermarkets.

An attractive package was developed which included instructions for use and recipes.

The product has been demonstrated to dieticians and chefs, and has been favorably received. Several commercial companies have expressed an interest in using minced fish in their products.

REFERENCES

Anderson, M. L. and E. M. Ravesi. 1969. Reaction of free fatty acids with protein in cod muscle frozen and stored at -29°C after aging in ice. J. Fish Res. Bd. Canada 26:2727-2736.

Anderson, M. L. and E. M. Ravesi. 1970. On the nature of altered protein of cod muscle stored at -29°C after aging in ice. J. Food Sci. 35:199-206.

Association of Official Agricultural Chemists. 1965. Official Methods of Analysis, 10th ed. Assoc. of Official Agr. Chemists, Washington, D. C.

Association of Official Agricultural Chemists. 1976. Bacteriological Analytical Manual for Foods, 4th ed. Assoc. of Official Agr. Chemists, Washington, D. C.

Baker, R. C., J. M. Regenstein, and J. M. Darfler. 1976. Development of products from minced fish: Booklet 1. Seafood Chowders. New York Sea Grant Institute, Albany, N. Y.

Baker, R. C., J. M. Regenstein, and J. M. Darfler. 1976. Development of products from minced fish: Booklet 2. Seafood Crispies. New York Sea Grant Institute, Albany, N. Y.

Bykova, V. M. 1972. Improving the quality of minced fish made from frozen raw material. Rybnoe Khozyaistvo 48(12):48-51.

Castell, C. H., B. Smith, and W. J. Dyer. 1973. Effects of formaldehyde on salt extractable proteins of gadoid muscle. J. Fish Res. Bd. Canada 30:1205-1213.

Connell, J. J. and P. F. Howgate. 1968. Sensory and objective measurements of the quality of frozen stored cod of different initial freshnesses. J. Sci. Fd. Agric. 19:342-348.

Cowrie, W. P. and W. T. Little. 1966. The relationship between the toughness of cod stored at -29°C and its muscle protein solubility and pH. J. Food Technol. 1:335-343.

Dingle, J. R. and J. A. Hines. 1975. Protein instability in minced flesh from fillets and frames of several commercial Atlantic fishes during storage at -5°C. J. Fish Res. Bd. Canada 32:775-783.

Goodrich, D. C. and D. B. Whitaker. 1977. Retail market tests of frozen minced fish. A.E. Res. 77-6, Dept. Agric. Econ., Cornell Univ., Ithaca, N. Y.

Love, R. M. and M. K. Elerian. 1965. Protein denaturation in frozen fish. IV. The inhibitory effect of glycerol in cod muscle. J. Sci. Fd. Agric. 16:65-70.

Other Sea Grant publications of interest:

In this series:

SEAFOOD CHOWDERS. Development of Products from Minced Fish: Booklet 1. R. Baker, J. Regenstein, and J. Darfler. 32 pp. 1976. $.75

SEAFOOD CRISPIES. Development of Products from Minced Fish: Booklet 2. R. Baker, J. Regenstein, and J. Darfler. 24 pp. 1976. $.75

CREAMY FISH BITES. Development of Products from Minced Fish: Booklet 4. R.C. Baker, J.M. Regenstein, and J.M. Darfler, 27 pp. 1977. $.75

TASTY DISHES FROM MINCED FISH. Development of Products from Minced Fish: Booklet 5. R.C. Baker and J.M. Darfler. 21 pp. 1979. $.75

BATTERED AND BREADED SMELT. Development of Products from Underutilized Species: Booklet 6. R.C. Baker and J.M. Darfler. 15 pp. 1979. $.75

Of general interest:

SEAFOOD SOURCEBOOK. A consumer's guide to information on food from our oceans and lakes. New England Marine Advisory Service. 48 pp. 1978. $1.00

RETAIL MARKET TESTS OF MINCED SEAFOOD CRISPIES. D.C. Goodrich, Jr. and D.B. Whitaker, 10 pp. 1979. Free

NEW YORK SEA GRANT: THESES Vol. II, No. 1: 15 pp. 1979. Free

Of technical interest:

IN VIVO CLEARANCE OF ENTERIC BACTERIA FROM THE HEMOLYMPH OF THE HARD CLAM AND THE AMERICAN OYSTER. B.J. Hartland and J.F. Timoney. 4 pp. 1979. $1.00

LIPID COMPOSITION OF DARK AND WHITE MUSCLE FROM WHITE SUCKER (*Catostomus commersoni*). J. Mai and J.E. Kinsella. 8 pp. 1979. $1.00

MARICULTURE IN NEW YORK STATE. Proceedings of the Symposium. O.W. Terry and D.M. Chase. 96 pp. 1979. $1.50

FISHERIES. MESA New York Bight Atlas Monograph 16. J.L. McHugh and J.J.C. Ginter. 129 pp. 1978. $4.00

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
REGIONAL CENTRE
MANGALORE